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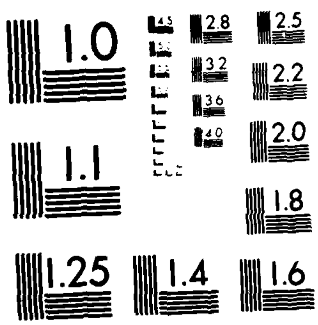
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The report describes an extension of the use of the Del Norte microwave transponder system to obtain improved accuracy of measurement of ice movements. Among the improvements was the use of two transponders on a single flow, making it possible to obtain rotational as well as translational movements. The ice flows were normal for marginal ice zone summer conditions. Flow sizes ranged from 30m to 200m, but a few large flows of 1-2km were present, ice thickness was 1-4m. Ice concentration ranged from 0.6 to 0.9 until 8 July 84, after which it declined to 0.3. Flows may rotate as much as 90° in a 24hr period.

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INVESTIGATION OF ICE DYNAMICS IN THE MARGINAL ICE ZONE

Principal Investigator: Dr. Matti Leppäranta

Contractor: Institute of Marine Research, Finland

Contract Number: DAJA45-83-C-0034

Fifth Periodic Report

1 June - 31 August 1984

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A-1

Fifth Interim Report

Investigation of Ice Dynamics in the Marginal Ice Zone

Dr. Matti Leppäranta

The entitled work was commenced by the author on January 24, 1983, at the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL), Hanover, NH, and is done in co-operation with Dr. William D.Hibler III from CRREL. In 1984 the author has continued this research at the Institute of Marine Research in Finland. The work includes both a theoretical and an experimental part. This report basically considers the planning, preparation and accomplishment of a measurement program in the MIZEX (Marginal Ice Zone Experiment) -84 field experiment in the Greenland Sea. Ice kinematics measurements were there made by Dr. Hibler, two technicians from CRREL (Stephen Decato and Keith Alverson) and the author.

MIZEX-84 experiment

The marginal ice zone in the Greenland Sea has been selected as the region of main field effort of the MIZEX-program (Wadhams et al., 1981; Johannessen et al., 1983). A pilot study "MIZEX-83" was carried through there in the summer 1983. Dr. Hibler and the author participated in MIZEX-83 and made detailed ice kinematics observations using the Del Norte microwave trisponder system. The method proved to be most valuable.

MIZEX-84 is the main summer experiment of the MIZEX-program. It took place in the Fram Strait in the Greenland Sea and lasted nearly three months, from mid-May to early August. Five research vessels were used and extensive remote sensing studies were carried through from satellites and aircraft. The Norwegian research vessel Polarqueen (chartered by the University of Washington) served as an ice station. She was moored to an ice floe at about 20 km from the ice edge and drifted with the ice for six weeks. Further general information on MIZEX-84 is given in Johannessen et al. (1983).

Our ice kinematics measurements were made on R/V Polarqueen. The total of about 30 scientists were aboard, mainly from the USA. During the experiment the Arctic sea ice edge lay around zero meridian west of Svalbard and close to 81°N north of Svalbard (Fig. 1). The location of R/V Polarqueen stayed in the northern part of Fram Strait through the whole experiment. Dr. Hibler was aboard through June and the author through July. Mr. Decato was aboard through the whole experiment and also took care of sending the instruments to the ship and back to the USA whereas Mr. Alverson was aboard only through July.

Ice kinematics in MIZEX-84

Our ice kinematics study was carried through using the Del Norte microwave trisponder system as in the pilot study a year earlier. Its accuracy is very good, 1-2 m. Based on those previous results the system was extended. The

main motivation was to obtain better spatial scale information on ice velocity fluctuations and to have degrees of freedom enough to analyze second order spatial velocity differences. It was also considered possible to use two Del Norte units on one ice floe to obtain data on rotation of individual ice floes. In fact, such measurements were made on two occasions.

Basically, the Del Norte system consists of a master station, slave station and several remote stations (Fig. 2). We had six remote stations this year. The direct distances from the master to the remotes and the range loops master-slave-remote-master are measured. One remote station was located at the same site as the slave in order to get the baseline (master-slave) length which is needed for triangulation. As can be seen from Fig. 2, the three measurements (d_o, d_i,b_i) for each remote give their positions in the coordinate system aligned with the baseline and the master station as the origin (the master was located on R/V Polarqueen). That is, the Del Norte system does not provide information of the location and orientation of the measurement array in the earth coordinate system. The latter was measured less accurately using radar reflectors on some remote sites but the former is not so important because we are studying differential motion in the ice pack. The location was, however, routinely determined with the ship's satellite navigation system. It should be noted that the invariants of the strain rate are independent of the rotation of the array and are thus accurately measured with the Del Norte system.

The measurement phase lasted from June 6 to July 18. In terms of the overall field operation there were no major problems and the system worked very well. For a few times a station had to be redeployed due to floe breakup or drifting too far from the ship. Two units began malfunctioning in late June but fortunately we had backups for them and they were replaced. Measurements were made at 15-minute intervals; this interval was based on the experience from MIZEX-83.

The units on the ice were mounted on the top of 4.5 m (remotes) or 6 m (slave) long pipes which stood with the help of rigid supports. These tripods, designed at CRREL, are very good on soft summer ice. Due to their height the units must be within a circle of about 15-km radius in order to get signals from the master and send them back.

Ice conditions were typical marginal ice zone summer conditions. Floe size was generally 30 to 200 m but a few large floes of 1-2 km appeared. In MIZEX-83 such large floes were not seen close to the drifting station. Ice thickness was 1 to 4 m. Ice concentration ranged from 6 to 9 tenths through most of the experiment but after July 8 there was a general diverging trend and the concentration went down to about 3 tenths till the end of the measurement phase.

In general terms the deformation of the ice pack had similar characteristics as in MIZEX-83. However, a careful analysis of the data may reveal differencies in details since the floe size distributions were different.

The array configuration and overall long-term character

of the deformation is shown in Fig. 3. Three sites were redeployed on July 3-4. In the early part the deformation had an oscillatory nature and so the total deformation was small. The general divergence began on July 8. Several sites had to be redeployed since they run away from 5 to 15 km distance in 2-3 days. This diverging situation lasted till July 18 when the system was recovered.

A redeployment was made on July 12 and it was then considered to be a worthed to measure the rotation of floes also. The pack was relatively open and floes were able to move without colliding with each other. Consequently two sites were each equipped with two remote stations about 100 m apart from each other (Fig. 4), and this configuration was used till the end of the measurement phase. It appeared that floes may rotate ninety degrees in a day which is much more than in compact ice cover.

This data set combined with our MIZEX-83 data represents a unique set if measurements of the deformation field of a series of interacting floes floating in the ocean. MIZEX-84 time series is longer and a larger number of stations has been used than in MIZEX-83. The floe size characteristics were different which may result in differences in some details of deformation processes. These data should greatly increase our understanding of marginal ice zone kinematics and dynamics. Because of the coincidence of current and wind measurements these data are most useful in modeling work.

References

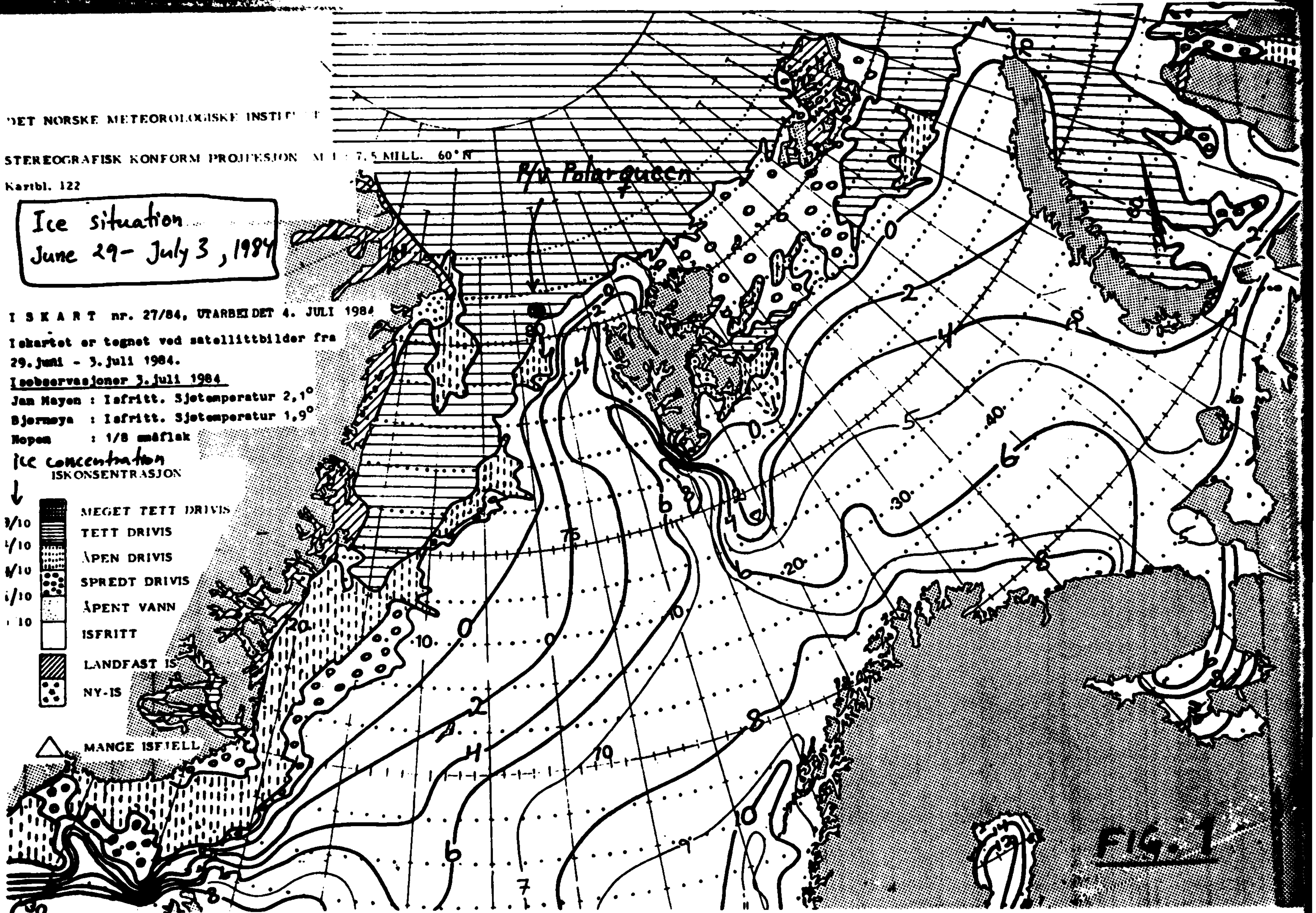
Johannessen, O.M., W.D. Hibler III, P. Wadhams, W.J. Campbell, K. Hasselmann, I. Dyer and M. Dunbar (eds.), 1983a: MIZEX. A mesoscale air-ice-ocean interaction experiments in the Arctic marginal ice zones. II. A science plan for a summer marginal ice zone experiment in the Fram Strait/ Greenland Sea: 1984. CRREL Special Report 83-12, 47 p. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H.

Wadhams, P., S. Martin, O.M. Johannessen, W.D. Hibler III and W.J. Campbell (eds.), 1981: MIZEX. A program for mesoscale air-ice-ocean interaction experiments in the Arctic marginal ice zones. I. Research Strategy. CRREL Special Report 81-19, 20 p. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H.

ANNEX

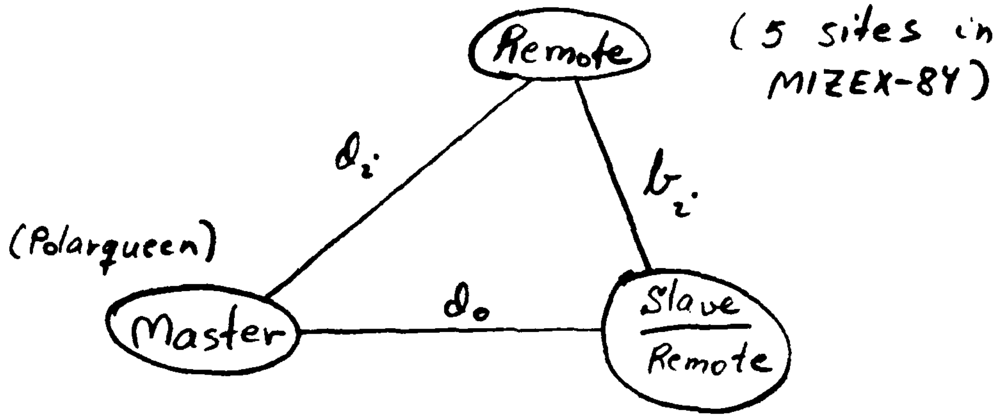
a. The amount of unused funds: none

b. Important property required: none



DET NORSKE METEOROLOGISKE INSTIT
STEREOGRAFISK KONFORM PROJEKSJON M 1 : 7.5 MILL. 60° N
Kartbl. 122
Ice situation
June 29- July 3, 1984
R/V Polarqueen
ISKART nr. 27/84, UTARBEIDET 4. JULI 1984
Iskartet er tegnet ved satellittbilder fra
29. juni - 3. juli 1984.
Isobservasjoner 3. juli 1984
Jan Mayen : Isfritt. Sjøtemperatur 2,1°
Bjørnøya : Isfritt. Sjøtemperatur 1,9°
Hopen : 1/8 småflak
Ice concentration
ISKONSENTRASJON
MEGET TETT DRIVIS
TETT DRIVIS
ÅPEN DRIVIS
SPREDT DRIVIS
ÅPENT VANN
ISFRITT
LANDFAST IS
NY-IS
MANGE ISFJELL

FIG. 1



Measured : $\begin{cases} d_o \\ d_i \\ s_i = d_o + b_i + d_i \end{cases}$ $\quad (i = 1, \dots, 5)$

Fig. 2. Del Norte system in MIZEX-84.

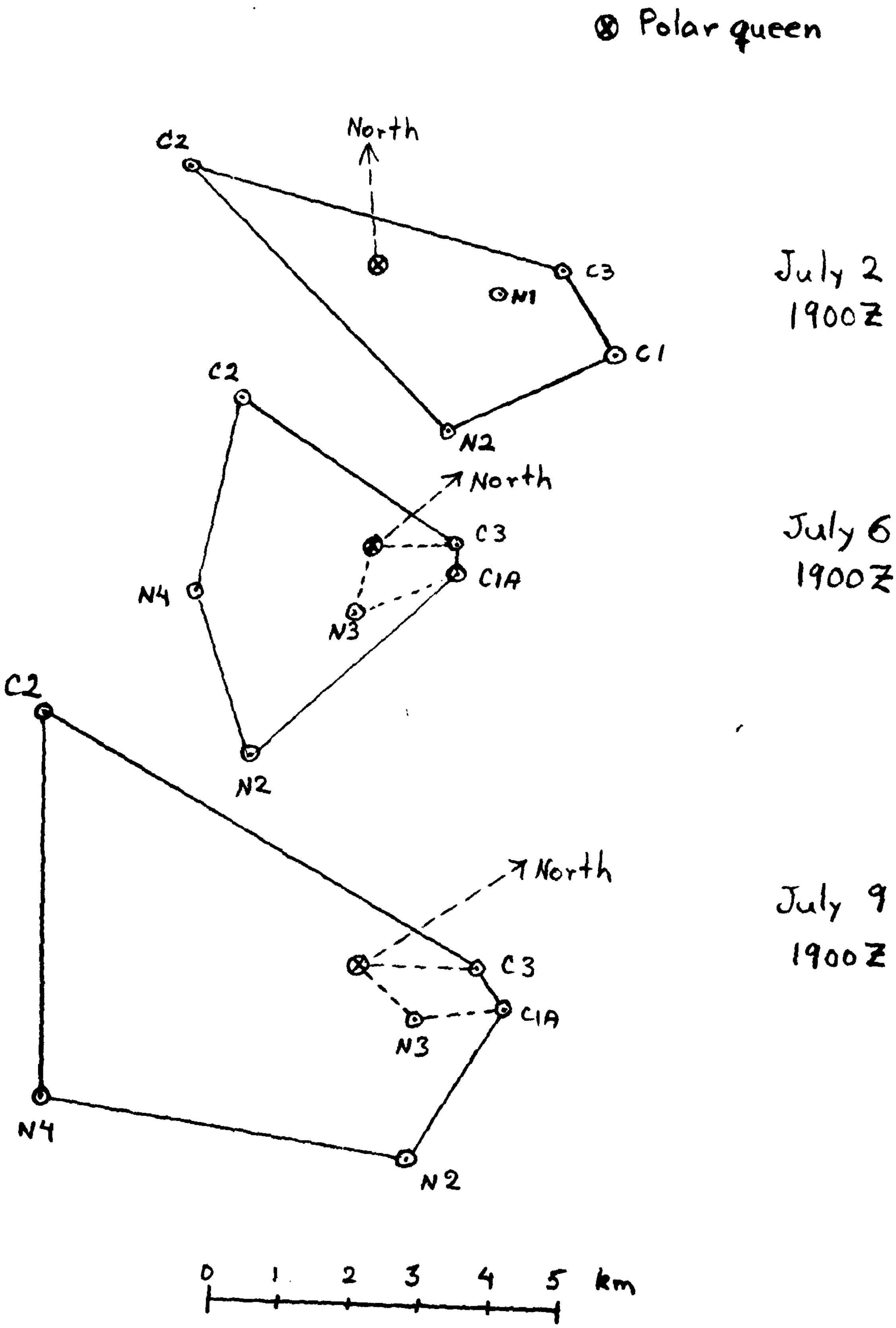


Fig. 3. Array configuration in July.

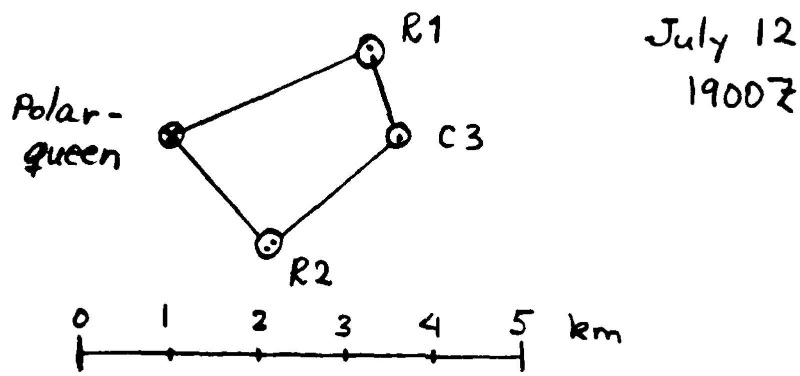


Fig. 4. Array configuration in the deformation and floe rotation measurement period.